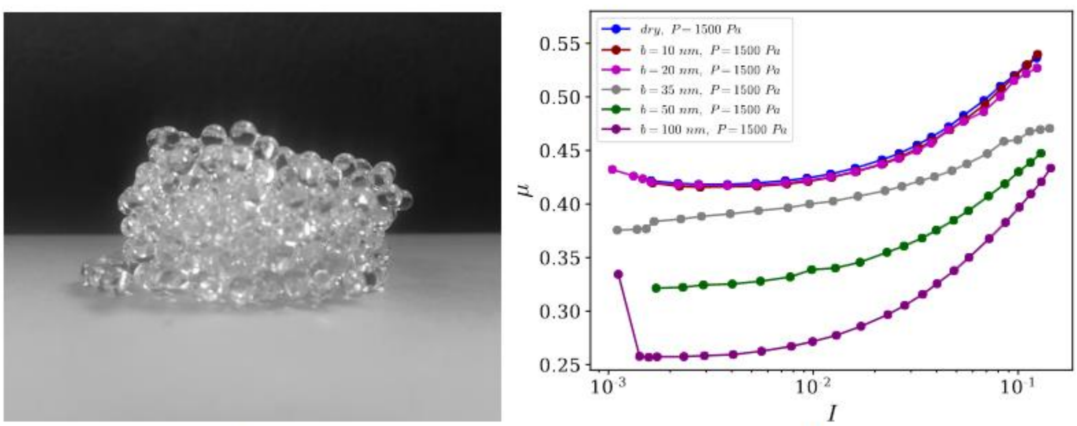
Thesis Proposal:

“Rheology of cohesive model powders”

Granular materials are among the most widely used primary resources globally, particularly in industry. Among the diverse range of granular materials, cohesive powders are some of the most delicate to handle. Understanding the behaviour of these powders in flow and developing tools tailored to their manipulation is thus a major industrial challenge. However, studying these cohesive powders is challenging due to the variety of cohesive interactions between the grains composing them.

Therefore, the objective of this thesis is to enhance our understanding of granular interactions within powders through the study of two parameters: cohesive and frictional interactions within granular media. The subject focuses on the production of granular particles with controlled surface properties and the effects of these surface properties on granular flows. A first method of particle production involves coating glass beads of defined diameter with a polymer (PDMS, see Figure 1 (a)). For low-pressure flows (such as silo or column collapse) and significant PDMS quantities (greater than 200nm of coating), it has been demonstrated that this method induces particle-particle adhesion, resulting in cohesion at the granular medium scale [1, 2]. Regarding high-pressure flows (see Figure 1 (b)), it has been shown that a low particle coating (less than 50nm) induces lubrication of particle contacts, reducing effective friction between grains. Experiments under controlled pressure (rheometry, silo drainage, etc.) for different coatings would thus allow for the identification of the predominance of frictional and cohesive effects depending on the pressure exerted on the granular medium.



(a) (b)

Figure 1: (a) Sample of cohesive particles coated with PDMS and (b) measurements of the granular friction coefficient under imposed pressure for different coatings.

A second controlled particle production method involves nesting two cylindrical capillaries. Each capillary is injected with a liquid phase. At the output of the inner capillary, for a chosen flow rate ratio, and if the phases are immiscible, droplets are formed with sizes controlled by the input flow rates (see Figure 2). The advantage of this setup is the ability to choose the chemical properties of the dispersed phase, often a polymer, so that the droplets thus manufactured then pass through a thermo-chemical treatment zone to obtain solid grains whose properties can be controlled. This treatment zone may consist of UV insolation and/or heating, or even mixing with other continuous or dispersed phases to achieve desired chemical reactions.

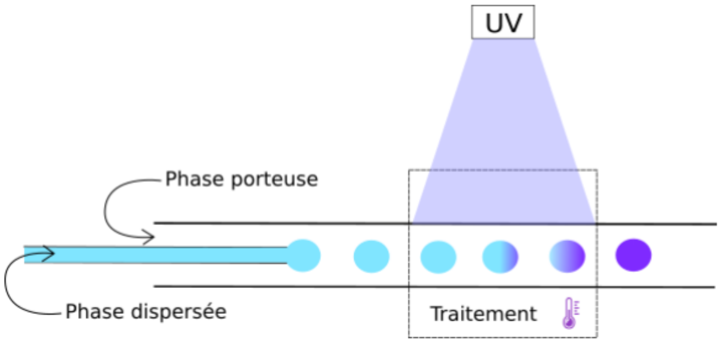


Figure 2: Microfluidic Device for Controlled Particle Production

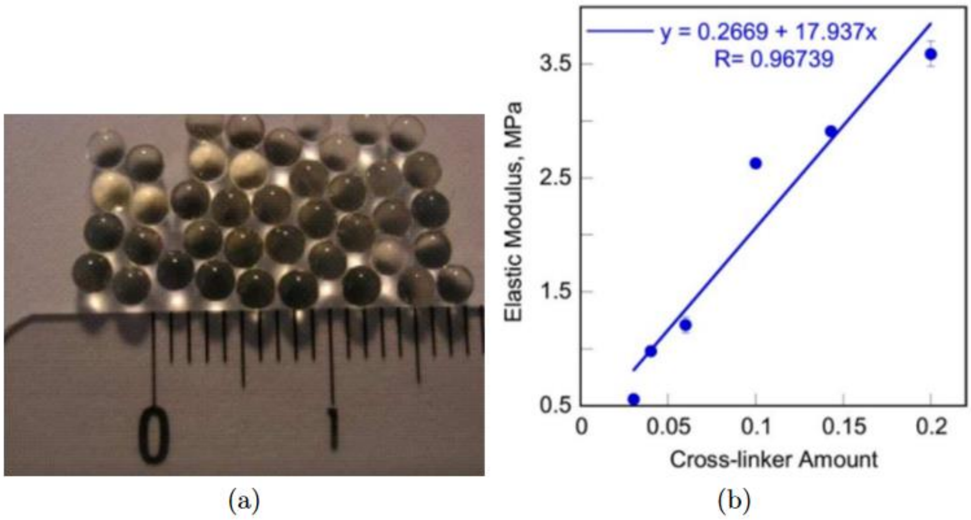


Figure 3: Example of controlled-size particle production (a) and controlled stiffness (b), extracted from [4].

This approach has already enabled the fabrication of controlled particles in several studies in recent years, particularly in controlling friction [3] and particle stiffness [4, 5, 6] (see Figure 3). Particles produced using this method would allow access to friction/cohesion torque values different from those obtained via the previous method, particularly through the control of grain stiffness.

This thesis will also be conducted in collaboration with Yoann Cheny from the University of Lorraine (LEMTA), where measurements obtained during flows can be used for the identification of rheological parameters via Physics Informed Neural Networks (PINNs) methods. Collaboration with Dr. Alban Sauret from the University of Santa Barbara is also being considered.

Funding: Secured

Location: University of Lorraine (Nancy, France)

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Keywords: Powders, granular materials, microfluidics

References

[1] A. Gans, O. Pouliquen, and M. Nicolas, "Cohesion-controlled granular material," Physical Review E, vol. 101, no. 3, p. 032904, 2020.

[2] A. Gans, A. Abramian, P.-Y. Lagree, M. Gong, A. Sauret, O. Pouliquen, and M. Nicolas, "Collapse of a cohesive granular column," Journal of Fluid Mechanics, vol. 959, p. A41, 2023.

[3] A. Galliano, S. Bistac, and J. Schultz, "Adhesion and friction of pdms networks: molecular weight effects," Journal of colloid and interface science, vol. 265, no. 2, pp. 372–379, 2003.

[4] D. Gilbert, R. Valette, and E. Lemaire, "Impact of particle stiffness on shear-thinning of non-brownian suspensions," Journal of Rheology, vol. 66, no. 1, pp. 161–176, 2022.

[5] J. Qu, L. Ouyang, C.-c. Kuo, and D. C. Martin, "Stiffness, strength and adhesion characterization of electrochemically deposited conjugated polymer films," Acta biomaterialia, vol. 31, pp. 114–121, 2016

[6] P. Panizza, W. Engl, C. Hany, and R. Backov, "Controlled production of hierarchically organized large emulsions and particles using assemblies on line of co-axial flow devices," Colloids and Surfaces A: Physicochemical and Engineering Aspects, vol. 312, no. 1, pp. 24–31, 2008